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Working plan for studying the effects.



WORKING PLAN

FOR STUDYING THE EFFECTS OF TIMBER HARVESTING  
AND VEGETATION REMOVAL ON STREAMFLOW, SEDIMENT,  
AND WOOD PRODUCTION OF PINE-FIR FORESTS OF ARIZONA,  
AS DETERMINED FROM THE WORKMAN CREEK WATERSHEDS,  
SIERRA ANCHA EXPERIMENTAL FOREST

by

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Reasons For the Study

Water has always been critical in the Southwest. It is extremely limited in supply. Lands that produce the major portion of the usable water are less than 2 percent of the total land area. Consequently, it becomes increasingly important to know how to properly manage these limited water-producing areas for the maximum quantity and quality of usable water. An analysis of the water and sediment problems of the Southwest points up the fact that the areas that produce the perennial streams are largely the pine-fir forests. Accordingly a question of immediate concern is how best to manage pine-fir forests from the standpoint of maximum water yield and at the same time achieve satisfactory timber production and minimum sediment.

Some water users claim that vegetation greatly reduces the total amount of water available, to the detriment of agricultural and industrial interests. Others recognize the fact that vegetation uses water but that other values resulting from vegetation amply justify the water used. Specific information is needed, therefore, to determine the values of vegetation in the high forested areas in maintaining sustained streamflow, controlling sediment, and protecting valuable downstream property from devastating floods. Information is also needed to provide the most economical and practical methods of managing the higher mountain watershed lands to



maintain and/or increase the usable water supplies and to check or reduce the sediment that is filling surface reservoirs and irrigation systems.

#### Objectives of the Study

The objectives of the study are as follows:

1. To determine by progressive steps of vegetation eradication how the different kinds and amount of vegetation influence water production.

2. To evaluate timber management practices directed toward high production of water and wood and to determine what influence timber removal and the accompanying logging and road-building operations have on the increase of sediment.

#### Results in Other Locations

Numerous examples are available on the influence of vegetation on surface runoff and erosion. However, the advantages, effect, and limitations forest cover has on modifying streamflow and controlling sediment, on a watershed basis, are limited to a few studies. In most of these the water yield was greater when the forest cover was reduced. The Coweeta<sup>1/</sup> Experimental Watersheds in North Carolina have provided some excellent information on the influence a hardwood forest has on water and sediment. When all of the vegetation was removed and left on the ground, the streamflow the first year was increased 65 percent without

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<sup>1/</sup>Hoover, M. D. Effect of removal of forest vegetation upon water yields. Trans. Amer. Geophys. Union, Part VI, 969-975. 1914.



any indication that the quality was impaired. By riparian cutting another watershed 15 feet on a vertical interval from the main stem, the streamflow was increased 20 percent.

On another area the effects of logging were strikingly shown in the quality of the water. The turbidity increased from 120 parts per million for the check area to over 6,000 parts per million for the logged area. The Wagon Wheel Gap<sup>2/</sup> study also indicates that streamflow will respond to complete forest removal; the average water yield for a 7-year period was increased 15 percent.

Studies in Colorado in the lodgepole pine type<sup>3/</sup> indicated that timber cutting exerted pronounced effects on the factors that influence streamflow and sediment. On the uncut plots, 10.34 inches of precipitation was available for streamflow. In contrast, the heavily cut-over plots produced 13.52 inches or an increase of 31 percent in the quantity of water available for streamflow, with no visible effects of erosion apparent.

A number of investigations have been made on the influence of fire and its effect on runoff, notably the Fish Creek fire in the chaparral type of California. Hoyt and Troxell<sup>4/</sup> compared the runoff of Fish Creek with a neighboring watershed that was not burned. It was found that in the first year following the fire

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<sup>2/</sup>Bates, C. G., and Henry, A. J. Forest and streamflow experiment at Wagon Wheel Gap, Colo. Monthly Weather Review Rev., Sup. 30, 1928.

<sup>3/</sup>Wilm, H. G., and Dunford, E. G. Effect of timber cutting on water available for streamflow from lodgepole pine forest, U. S. Dept. Agr. Tech. Bul. 968. 1948.

<sup>4/</sup>Hoyt, W. G., and Troxell, H. C. Forests and streamflow, Trans. Amer. Soc. Civil Eng. 99: 1-111, 1934.



there occurred a 231 percent increase in runoff over the estimated normal of 1.07 inches. The flood peak which was ordinarily 2.5 times the maximum daily discharge prior to the fire increased 16.2 times. The sediment collected over a 4-month period immediately following the fire showed a sediment content from 20 to 67 percent by volume or as high as 40 percent by weight. It can be concluded from this study that burning increased the water but it was of questionable value because of the quality.

These results indicate that water available for streamflow can be increased by the removal of the forest cover; that certain kinds of vegetation consume or intercept more water than other kinds; and the largest increases seem to occur when vegetation needs are highest. Specific information on the conditions affecting plant, soil, and water relations need to be worked out for the pine-fir forest of the Southwest<sup>5/</sup> to facilitate satisfactory watershed management. Most of the studies so far indicate what the maximum effect would be by removing part or all of the forest<sup>6/</sup> cover. The effects of different cutting methods of forest cover on water and sediment and wood need to be determined for the pine-fir forests.

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<sup>5/</sup>Considered to be Arizona, New Mexico, and west Texas.

<sup>6/</sup>Forest is considered throughout this report to include both arborescent and shrubby vegetation.



### The Study Area

Workman Creek (part of the Sierra Ancha Experimental Watersheds north of Globe, Ariz.) consists of a three-forked, bowl-like watershed of 1,087 acres which generally drains to the west. Each of the three forks is tapped by a small perennial stream. A north fork enters from the northeast, a south fork from the southeast, and a middle fork drains the area between (see map of area, fig. 1). The elevation ranges from 6,590 feet at the main stream-gaging station to 7,724 feet at Aztec Peak, the highest point. Ponderosa pine, Douglas-fir, and white fir constitute the main timber type. Gambel oak is intermixed and makes up a considerable portion of the stand on the south and west exposures. Precipitation averages about 32 inches per year. Approximately 12 inches appears during the months of June through September and about 20 inches during the winter period October through May. Snow accounts for nearly two-thirds of the winter precipitation.

Weir installations were made in 1938 and a flume installed in 1952. Streamflow is measured separately for each watershed and for the entire area.

### Existing Records

Since 1938, records, surveys, and inventories have been made of the major physical and biological conditions. These measurements, made essentially under virgin forest conditions, include intensity and amount of precipitation, surface runoff and erosion, climate, soils, vegetation, underground water conditions, and geology. They serve to establish a basis for evaluating future



# WORKMAN CREEK WATERSHED



Figure 1. Timber Density Classes

- A - Areas with 200 to 280 sq.ft. basal area per acre
- B - Areas with 120 to 200 sq.ft. basal area per acre
- C - Areas with 40 to 120 sq.ftt basal area per acre

~ Watershed boundary



changes that may occur on the watershed as the result of treatment. For example, it is expected that there will be an increased amount of organic material added to the soil when all the dead vegetation is left on the ground. How long this effect will last and how it will influence the functions of the soil will be difficult to determine at the outset. However, with the soil inventories of the original conditions, it will be possible to set up studies to evaluate any changes that may occur.

With the inventory data as a background, management practices will be evaluated in terms of their effectiveness in maintaining, increasing, or controlling water and sediment through the various methods of timber cutting.

A more detailed discussion of the records and inventories is included in Appendix A.

#### Methods of Investigation

The three forks of Workman Creek are available for treatment. Middle Fork will be kept as a climatic check throughout the study. North Fork will have the timber cut and left on the ground, with as little disturbance to the soil as possible, and South Fork will be logged to resolve any detrimental effects logging has on water and sediment and to determine the influence good timber production has on maximum water and sediment yields.

Duplication of treatments is not feasible. Consequently, the treatments applied on ~~North~~<sup>South</sup> Fork where the timber is logged will be compared only with Middle Fork or check area. Likewise, the results from ~~South~~<sup>North</sup> Fork on which the timber is left on the ground will be compared only with the check watershed.



The amount of sediment removed and the character and amount of runoff and permanent streamflow coming from the watershed will measure the treatments applied.

The treatments to be applied are shown in figure 2. These include:

1. North Fork

a. Cutting all the water-loving vegetation

All of the broadleaf species, such as the alder and maple, that require large amounts of water during the growing season, growing along the living stream or immediately in or adjacent to seeps and springs, will be cut at the ground level and laid on the forest floor. No attempt will be made to fell the trees in any pattern other than away from the main stream course. Tops and limbs will be lopped from the larger stems and the material scattered uniformly over the ground to form a loose mulch. To guard against excessive soil disturbance and to hold erosion to a minimum, none of the vegetation will be removed or salvaged. It is anticipated that the killing of this high water-consuming vegetation will increase the amount of water passing over the weir and thus provide a basis for determining the amount of water used by this type of vegetation. It will also indicate whether or not eradication of this type of vegetation can be justified for increased water returns.

b. Cutting vegetation that receives additional seepage water

Other riparian vegetation along the main stream channel that receives additional seepage water will be cut and left on the forest



## WORTHEN CREEK WATERSHEDS

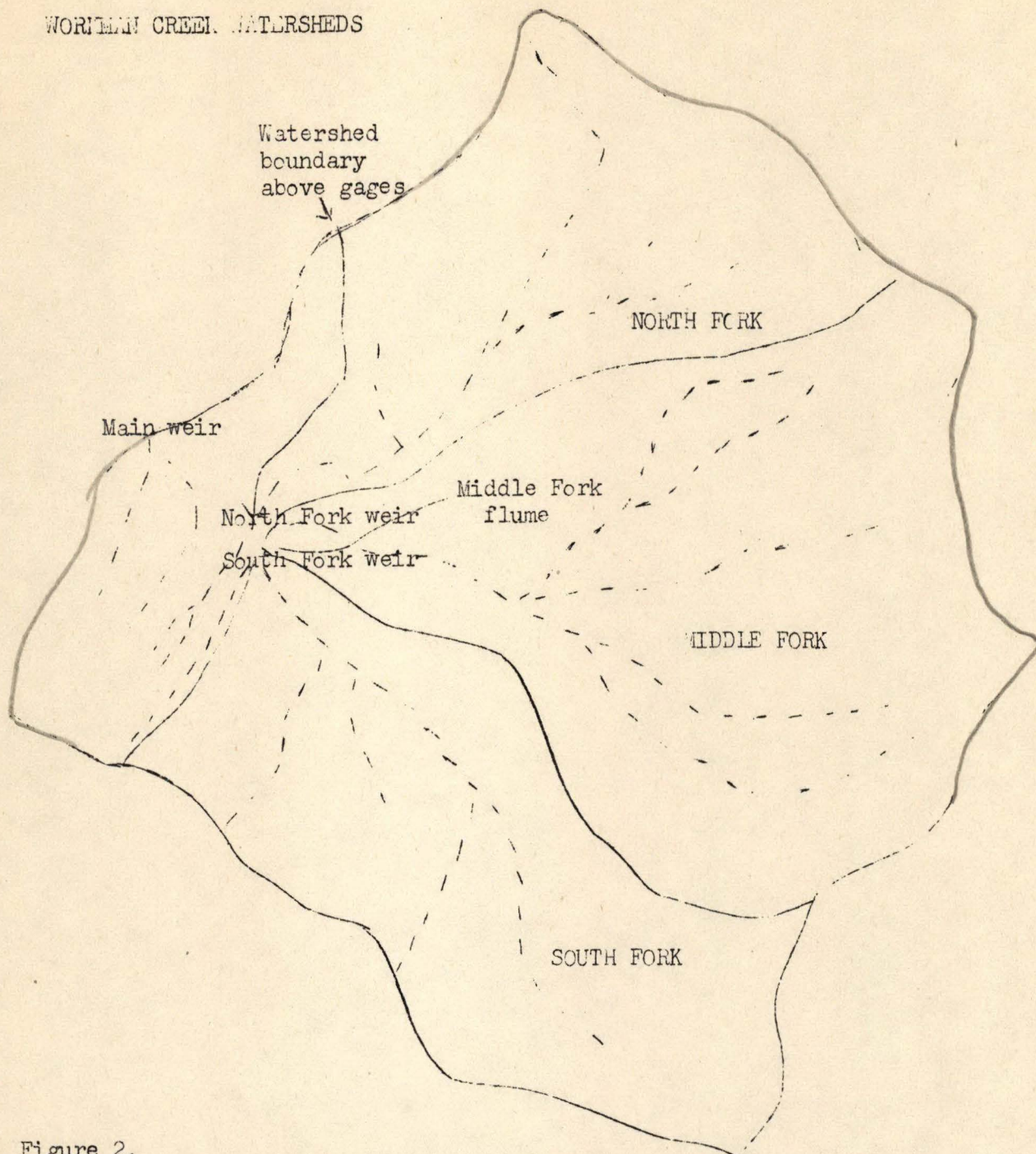


Figure 2.

North Fork. All timber to be left on the ground as treatments progress.

First treatment, cut all vegetation around seeps and springs. Second cut, remove wet-site vegetation. Third cut, remove all moist-site vegetation (fir and similar species). Fourth cut, remove all vegetation.

South Fork. First treatment, remove approximately 50 percent of merchantable volume plus improvement cuts to bring total cut to 35 percent of total basal area. Second cut, further reduction in basal area to minimum that will permit good growth (80-100 sq. ft. per acre). This will be about 25 percent of remaining merchantable volume plus improvement cuttings.

Middle Fork. Will be maintained as a climatic check throughout the proposed cutting treatment of the other watersheds.



floor. Care will be taken in felling the trees to cause as little disturbance to the soil mantle and main stream course as possible. Treatment of the cut timber will be handled much the same as that described under (a). Sprout growth will be cut back as needed to maintain a minimum plant cover. The vegetation to be cut will vary according to the steepness of the slope, soil conditions, and the watershed area above the channel. It is anticipated that this treatment will furnish data for appraising the contention that vegetation along the bottom of permanent stream courses should be removed to increase water supplies.

c. Cutting vegetation on the moist sites

All of the vegetation will be clear cut from the moist sites as the third treatment. Moisture conditions of the soil such as the water-holding capacity, density, aggregation and infiltration rate of the soil will be related to the percent of fir composition as a basis for selecting the sites to be cut. Where the fir composition makes up the major portion of the stand and the soil conditions indicate a high water-holding capacity, all of the vegetation will be cut and laid on the forest floor with as little disturbance to the soil as possible. Limbs will be removed and the main stems left in contact with the soil as described for the earlier treatments. During the course of this treatment the vegetation will be kept down either by poisoning or by actual hand cutting the recurring vegetation. This treatment should remove that vegetation which apparently has a larger supply of moisture during the dry portions of the year. It will provide a basis for further



evaluating the desirability of heavier timber removal in the pine-fir type for increasing water supplies.

d. Clear cut dry-site vegetation

This treatment will follow the other cutting practices on North Fork. The intent of the treatment is to cut the remaining dry-site, woody vegetation on the watershed. Sprouting species will be recut or killed each year and more often if necessary, if growth is extensive. All vegetation will be left on the ground as it falls and will be treated in similar manner to the previously described treatments. There will be no timber removal to avoid disturbing the soil mantle. After the watershed has been evaluated without vegetation, the vegetation will be allowed to return and its effect on water and sediment recorded.

2. South Fork

Harvest on an individual tree selection basis for optimum quality and quantity of wood and water

The objective of the treatments on the South Fork will be to harvest the timber for the maximum production of water and pay for it to a maximum degree with good quality timber. It will be the policy to carry out a more vigorous thinning and stand improvement program than may be economical under present policy and price conditions. Little information is available on the maximum amount of wood that can be grown and at the same time not interfere greatly with <sup>maximum</sup> water yields. The cuttings on this watershed will be carried out with this objective in mind.

The first cutting will remove approximately 35 percent of the total canopy. This will be accomplished by harvesting about



40-50 percent of the merchantable volume and obtaining the desired additional canopy removal by improvement cuttings, oak removal, and thinning. Oak and mistletoe-infected trees will be removed during the first cut where practical. With this removal and the removal of some of the large fir, ponderosa pine should be favored.

During the second cutting cycle the objective will be to further open up the canopy through improvement cutting, thinning dense stands of poles, and clearing up the remaining mistletoe infections by taking 25 percent of the merchantable volume. This treatment should improve the stand and open up the canopy so that more precipitation reaches the ground, thereby reducing interception losses, and at the same time improve timber growth and increase water available for streamflow.

The effect of logging on sediment will be determined by the amount of erosion taking place over the watershed. This will be evaluated by sampling soil displacement over the watershed, cross-sectioning the channel and placing catchment basins over the watershed.

#### Experimental Design

The study will follow a simple design with one management treatment following another, with a period of measurement after each treatment.

A series of extremely dry years as well as wet years have been studied. While there are variations in the watersheds, there is a highly significant correlation between streamflow between watersheds and precipitation for all watersheds. (See Appendix, p. 21)



Each watershed will be treated as a unit, holding one watershed as a check against the other two. The severity of the treatment and amount of timber removal will be progressively increased as the separate treatments are applied so that two or more treatments can be applied to each watershed, one after another. Once the effect of the first treatment on water and sediment has been obtained, careful observations and statistical checking will largely eliminate any question that one treatment will influence another.

The length of the period of measurement after cutting will be determined by the number of years above and below the normal, and the amount of increase in water yield.

Based on past precipitation records, a good estimating equation has not been developed for each watershed; consequently it is not possible to treat all three watersheds and use past performances of streamflow and precipitation as the climatic check. Rainfall appears to be the most logical basis for estimating streamflow. However, inspection of existing data shows rather wide variations: for example, 28.5 inches of precipitation yielded 1.77 inches of water on South Fork, while 25.5 inches in 1947 yielded 3.10 inches, and 21.23 inches in 1948 yielded 1.81 inches of water. From the diurnal fluctuations, the growing season extends from April through September and probably includes part of October. The remaining part of the year can be divided into the recharge period, October and November, and the storage period, December through March. Rainfall considered in these three periods and correlated with annual runoff appears highly significant, but a comparison of past



years' records with estimated flow shows errors as high as 35 percent. Consequently it may be risky to base an equation on only 1 year of high flow with the majority of years below an estimated long-time average, particularly if the treatment period should include years between these two extremes.

The treatment differences required to show significant divergences for a 5- and 12-year period of streamflow are shown in table 1, page 15.

#### Records to be Taken

Records similar to those kept during the calibration period will be continued. These include:

a. Climate. Temperatures (soil and atmospheric), wind velocity, evaporation, and precipitation--these will be kept according to the standard U. S. Weather Bureau procedure.

b. Streamflow and sediment measurements. Streamflow will be measured by V-notch and Cipoletti weirs and a trapezoidal flume, and recorded on water stage recorder charts. Sediment will be measured cross-section over the watershed by weekly turbidity samples of the streamflow and the amount of sediment caught in the weir ponds.

c. Soil moisture. Weekly soil-moisture readings will be made through the use of Colman moisture elements randomly placed over the watersheds. These will be correlated with standard rain gages at each location.

d. Vegetation. A tally will be kept of the number of trees cut, by species and diameter classes; also board-foot volumes removed



will be determined for each species cut. One hundred foot line transects will be used for measuring the understory. A series of growth measurements will be made on the permanent timber sample plots to check on the increase or decrease in the volume and quality of growth as related to water and sediment. Cost records will be kept of all cutting operations connected with each practice.

e. Sediment measurements. Turbidity samples of the stream-flow going over the weirs will be taken at regular intervals throughout the cutting treatments. In addition sediment will be measured in the catchment basins and profiles will be established over the watersheds as a further check on sediment losses. These profiles will be closely linked with soil type, slope, vegetation, skid trails, and roads.

f. Underground water. Daily fluctuations in the groundwater level in wells will be recorded on water stage recorder charts.

The experimental layout will permit additional measurements as needed and as funds and personnel are available. To illustrate: Measurements of raindrop splash related to vegetation cover may be desirable. It may be desirable to determine the distribution and development of gullies with surface erosion. Additional measurements to evaluate the influence of snow and its relation to infiltration and water storage may be desirable. The use of radioisotopes may be tried, to follow the movement of water through soil and through a watershed. The influence of the vegetation on interception, shading, the microclimate and macroclimate may be desirable.



### Analysis

Two questions will be answered by an analysis of the streamflow: (1) Did manipulation of vegetation increase streamflow and sediment and by how much? and (2) Was there a consistent increase in streamflow? The analysis should take into account the time with which significance might be obtained. It appears from the data analyzed to date that the method of covariance, using one watershed as a climatic check, is the best method for obtaining the most reliable answers in the shortest period of time.

Correlation coefficients range from 0.9807 for streamflow between South and Middle Forks and 0.9832 for streamflow between North and Middle Forks to 0.9893 for streamflow between South and North Forks. The number of years necessary to show statistical significant differences due to treatments, however, points out differences in the watershed to be held as the climatic check and the watersheds to be treated. Table 1 shows the treatment differences required to show significance on a 12-year calibration period and also on a 5-year period. After treatments are started, the actual length of the treatment will depend on the differences that actually show up through treatments.

Treatments will need to be severe enough to show that the differences are both worth while and not due to chance, without requiring an unduly long period evaluation.

The above method disregards rainfall and considers that rainfall is similar on all watersheds and differences are reflected in both the treated watershed and the watershed held as a climatic



check to the same extent. Also correlation coefficients on a monthly basis are not as good as those on an annual basis.

Table 1.--Treatment differences required to show significant differences for a 5-year and a 12-year treatment period

		Difference needed to show significance			
		: Watershed		: For a 12-year period	
Watershed : held as		: Pct. of		: Pct. of	
treated : check		: Inches		: Inches	
		: avg. an-		: avg. an-	
		: nual flow		: nual flow	
South Fork North Fork	0.55	16.5	0.26	7.8	
South Fork Middle Fork	.74	22.2	.35	10.5	
North Fork South Fork	.82	24.9	.39	11.9	
North Fork Middle Fork	1.03	31.3	.49	14.9	
Middle Fk. South Fork	1.30	41.9	.62	20.0	
Middle Fk. North Fork	1.22	39.4	.58	18.7	

An estimating equation based on precipitation and stream-flow fails when streams are both rain and snow fed and subject to extreme climatic changes. Some years the precipitation is chiefly in the form of rain, other years as snow, with very little rhyme or reason as to the amount of streamflow that may be expected. For this reason the calibration curves may fail should the treatment period contain a number of years that fit between these two extremes where there is no calibration data. Also, there is wide variation in yearly streamflow characteristics among the three watersheds. South Fork, with its north aspect, is a more uniform flowing stream, while the North and Middle Forks, with their south and west aspects, have a much faster drain-out of winter precipitation and a lower water flow during the summer. In view of this condition, it is risky to attempt an estimating equation based on any one watershed.



By holding Middle Fork as a climatic check, treatment must be applied severe enough to increase the water yield by 10 percent. Assuming there are approximately the same variations in streamflow during the treatment period as during the calibration period, the analysis of covariance will be similar to that shown in table 2.

Table 2.--Analysis of covariance;<sup>1/</sup> effect of timber cutting on water yield from watershed A, adjusted to mean yield from watershed B

Line:	Source	Degree of freedom	Corrected squares and products	Regression coefficient	Degree of freedom	Sum of square *	Mean square
			$S_x^2$ $S_{xy}$ $S_y^2$	$\frac{S_{xy}}{S_x^2}$			
1	Total	23			22		
2	Periods	1			1		
3	Error 1-2 within periods	22			21		
4	Period 1	11			10		
5	Period 2	11			10		
6	Sum 4/5	-			20		
7	Within periods	-			21		
8	Diff.	-			1		

$$* S_y^2 - \frac{(S_{xy})^2}{S_x^2}$$

<sup>1/</sup>Wilm, H. G. How long should experimental watersheds be calibrated. Trans. Amer. Geophys. Union. April 1949.

It is realized that the annual runoff is based on the assumption that the mean square error variance is the same following treatment as before treatment, and that when treatment is applied, the treated watersheds will tend toward recovery of the vegetation and possible decrease in sediment. However, by keeping the vegetation in check during the entire treatment period, this should be largely overcome. It would be difficult to include and measure other physical variables as they changed with time, and as far as



known there is no better method of selecting watersheds for treatment and to provide adequate data in the shortest time.

The influence of the management treatments on sediment amounts, soil change, vegetation responses and changes due to the various treatments, and any other variations and relations can best be analyzed by regression analysis, and the regressions for the various watersheds can be analyzed by covariance. Some of the relations that will be considered are as follows:

1. Variation in summer, winter, and annual water yield against variation in crown and leaf area.
2. Variation in sediment yield against total leaf area.
3. Variation in surface runoff in summer and winter against total ground cover.
4. Variation and response of soil types to cover conditions.
5. Soil-moisture variations during the summer and winter and the effects of changing vegetation densities and types.
6. Physical and chemical soil changes in relation to changing management practices.
7. Relations and variations of logging practices to sediment yields and water quality.



APPENDIX A  
PHYSICAL CONDITIONS

Geologic conditions

Geologic conditions in the study area are typical of the rugged mesa-like Sierra Ancha Mountains. Most of the formations are essentially horizontal with local flexures caused by intrusions of basalt and diabase. The strata in the study area have a low dip to the westward with a small local flexure on the east side which dips gently to the east. High rugged cliffs are common to the entire range. An abrupt cliff some 200 feet occurs just above the main measuring weir.

The formations in the area consist of the underlying dripping springs quartzite (Cambrian in age) which is mostly a slabby dark brown to gray color. This has been intruded by diabase and basalt sills and plugs. The diabase has a characteristic yellow-brown color and weathers into a coarse granular sand. The basalt is a dense, massive, dark gray-brown rock that is very resistant to weathering. The troy sandstone (Upper Cambrian or Silurian) occupies the upper parts of the watershed and is a red to light gray sandstone. It varies in density according to its proximity to the igneous intrusions, being metamorphosed to a quartzite in many places.

Geologic development has determined the past erosion activity. Erosion to date has been largely geologic, with little accelerated erosion discernible on the watersheds. Most of the formations are dense and hard, offering considerable resistance to weathering. Surface examinations show the formations dip toward



the measuring weirs; consequently it is assumed that little water is lost through deep seepage or that any water from outside the watershed is measured.

#### Climatic conditions

Average annual precipitation in Workman Creek is the highest measured at any Weather Bureau station in Arizona for the 12-year period 1938-39 to 1949-50. Highest precipitation of record occurred in 1940-41 with a total precipitation of 52.8 inches, 166 percent of average. Lowest precipitation of record, 21.23 inches, was measured in 1947-48 and was 67 percent of average. Of the remaining 10 years of record, 5 were above average and 5 below average. About 69 percent of the total precipitation occurs during the winter period (October through May) in the form of low-intensity storms of long duration. The remaining 31 percent occurs largely as high-intensity storms during the summer (June through September). Precipitation is largely concentrated in two distinct periods. Nearly half of the year's total occurs during December, January, February, and March, and nearly 30 percent during July, August, and September. April, May, and June, on the average, account for only 8 percent of the year's total, and it is during this period that most droughts occur.

The average annual distribution is as follows:

<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Total</u>
2.31	1.84	5.32	3.96	3.20	3.16	1.43	0.55	0.51	2.32	3.14	3.90	31.64

Temperatures have been measured since 1941 and seldom remain below freezing for long periods. The coldest month in this period



was January 1946. The average temperature was 27° F., yet for only 9 days out of the month the temperature remained below freezing the entire day. During the other 22 days, temperatures exceeded 32° F. for at least part of the day. The average maximum for this month was 36.3° F., and the average minimum was 17.7° F.

Part of the winter precipitation occurs as snow but seldom results in a snow pack with a high total water content since there is some melting almost every day in the year.

Average monthly air temperatures between 1943 and 1948 are as follows:

<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>
37.5°	37.5°	32.5°	31.2°	32.1°	36.9°	44.2°	52.2°	55.8°	63.6°	64.3°	59.3°

#### Water levels in wells

Water levels in observation wells indicate a recharge period, followed by continuous drain-out. Water levels in two wells measured since June 22, 1948, show that the periods of maximum streamflow have coincided with the period of recharge in the wells. Summer and fall precipitation has not affected the water-surface elevation in either well. This fact is characterized by the following measurements taken of the Watkins well: On June 22, 1948, the water level was 7.94 feet below the top of the casing and by December 21 the water level had dropped to 15.10 feet. During the week of December 21-28, 1948, 7.09 inches of precipitation fell and the water table rose to within 3.35 feet of the top. The maximum height was reached March 8 (3.28 feet of the top) and was followed by a steady and continuous decline to December 27, 1949, when the water



level was 15.35 feet below the top of the well casing. Some recharge occurred between December 27 and February 14, 1949, and the water level rose to 9.95 feet. Between February 14 and February 28, as a result of 3.89 inches of precipitation, the water level rose to within 3.44 feet of the top of the casing. The drop in water level was steady and continuous to 15.75 feet by the end of the water year.

### Streamflow

Streamflow results mainly from winter precipitation. The average streamflow for the 12-year period of record has been similar from the three forks of the watershed, averaging from 3.10 inches from Middle Fork to 3.34 inches on South Fork. The period of record includes only one wet year, 1940-41, when streamflow was markedly above average. During this year streamflow was highest from Middle Fork while for most other years, as well as for the average, Middle Fork was lowest. The one wet year did much to balance out the three watersheds. The annual water yields are as follows:

### Water Yield in Inches

<u>Water year</u>	<u>South Fork</u>	<u>North Fork</u>	<u>Middle Fork</u>	<u>Precipitation</u> (Inches)
1938-39	2.68	2.11	2.36	32.30
1939-40	1.77	1.35	1.29	28.51
1940-41	8.65	11.16	13.02	52.86
1941-42	3.11	2.40	2.55	25.52
1942-43	3.80	3.56	2.79	33.08
1943-44	3.31	3.52	3.31	32.55
1944-45	4.20	4.99	3.81	30.29
1945-46	2.51	2.01	1.57	33.31
1946-47	3.11	2.26	1.82	25.52
1947-48	1.81	1.17	.94	21.23
1948-49	3.30	3.80	3.08	38.81
1949-50	<u>1.87</u>	<u>1.11</u>	<u>.69</u>	<u>25.76</u>
Average	3.34	3.29	3.10	31.64



Large variations in streamflow during the year are also characteristic of the area. The ratio of the highest month (March) varies from 5 times the month of low flow in South Fork to 30 times the month of low flow in the Middle Fork.

The average monthly yields for the three watersheds are:

	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Total</u>
<u>North Fork</u>	.071	.116	.289	.339	.486	.965	.575	.169	.072	.052	.059	.095	3.29
<u>South Fork</u>	.140	.174	.261	.249	.332	.685	.624	.292	.155	.133	.136	.163	3.34
<u>Middle Fork</u>	.042	.078	.294	.226	.435	.983	.715	.136	.042	.032	.032	.087	3.10

Streamflow for the period December through April averages 77 percent of the yearly total (varies from 64 percent on South Fork to 85 percent on Middle Fork). Precipitation during this period is 54 percent of the annual total. May and June are months of lowest precipitation (8.4 percent of the total). During these months streamflow is maintained by drain-out of winter precipitation that carries on into the summer months. The date of lowest flow usually occurs in July just before the summer rains. Since part of the base flow for the summer months also results from winter precipitation, the dominance of winter precipitation in producing streamflow is evident throughout the entire year.

In contrast to winter precipitation, summer precipitation yields much less streamflow. Rainfall during July, August, and September amounts to nearly 30 percent of the annual total, yet streamflow during these months amounts to only 5 percent on Middle Fork, 6 percent on North Fork, and 12 percent of the total annual flow on South Fork.



Each summer storm causes a sharp small rise in streamflow. There seems to be no point of contraflexure on the recession side of the hydrograph which points to channel storage as the source of the small rises. The stream beds on both North and South Forks are approximately 3,300 feet long. If the wet area, which is the average width of the channel, is considered as 7.5 feet wide on North Fork and 14 feet wide on South Fork, the precipitation that falls on the stream bed seems to account for the summer rises.

A relationship seems to exist between channel storage and immediate discharge following a summer storm. The most intense summer storm during the period measured occurred August 29, 1947. Total precipitation was 1.82 inches and the highest intensity for a 10-minute period was 4.20 inches per hour. This precipitation falling in the channel seemed to account for the total rise, except for a slight addition from the ground water flow. The only summer storm that resulted in streamflow in addition to channel storage was the big storm of September 17-19, 1946, when 7.55 inches fell in 50 hours. Maximum intensity occurred during the first part of the storm and was 2.70 inches per hour for the highest 10-minute period. When this precipitation was routed through the channel it accounted for the first rise. Four subsequent rises, even though resulting from much less intense precipitation, were much higher than the first, and the total quantity of water yielded was more than could have been accounted for by channel precipitation. As the soil reached field capacity, each additional storm contributed to streamflow. These rises can be accounted for as contributions



from areas of the shallow water table close to the channel where soil profiles are quickly saturated and drain rapidly. The total yield for this September 1946 storm varied from 5.5 percent on South Fork to 8.5 percent of the rainfall on Middle Fork. Streamflow, 4 days after the storm, however, was nearly as low as before the storm.

#### Sediment

The hydrographs of the rises in streamflow indicate very little surface runoff has occurred as a result of summer precipitation, a fact borne out by a study of the surface conditions and the very small amount of sediment caught in the stilling basins back of the weirs through the 12 years of stream records.

Weekly water samples have been taken at the three gaging stations since April 5, 1949. One sample of August 9, 1950, on main dam, just after a storm of 1.25 inches and after work had been done on the road between the main dam and the North Fork dam was 138 ppm. All the rest have been from 4 to 66 ppm. Heavier sediment is caught in the stilling basins behind the weirs. These will be cleaned just before treatment starts. However, observation indicates very little sediment has been caught, a point which substantiates the fact that little surface runoff occurs.

#### Soils and erosion

Forest soils are not static bodies and may be expected to change with modification of their environment. It is important that their present condition and the condition that might attend timber harvesting be inventoried. A method was developed for mapping and classifying the soils, based on those features that may



be expected to change with treatment. The most marked profile changes in soil were found to coincide with the type of rock from which the soil had weathered, and were found to directly affect the character of the soil body. Other field data recorded included texture, depth, structure, and color of the surface soil, the depth and degree of decay of the organic material, the percentage of rock covering the surface, the slope, and erosion. Table 1, Appendix B, sets up the key used to record the physical characteristics selected.

Three broad general soil classes--the soils derived from (1) diabase, (2) quartzite, and (3) sandstone--were mapped. Fifteen different soils types were separated and a description made of their profile characteristics to provide a basis for evaluating any organic or pH changes, change in volume, infiltration, compaction, or texture that may occur after treatment.

Laboratory analyses of these conditions are shown in Appendix B, along with the soil profile descriptions.

Generally the soils are of loam to clay-loam texture, with either granular or crumb structure. PH values average about 5.6. In most cases the subsoils are layered, heavy textured, and clay loams to clays.

The condition of the surface 6 inches of soil plus the litter cover seems to exert the major influence on the ability of the soil to absorb water and produce vegetation.

Slope, while not a soil factor, has been inventoried because of its function in relation to the soil body and its importance in any management or treatment of the land. The degree and length of



slope are two essential features that have a direct relation to runoff and erosion.

Present erosion conditions were recorded in conjunction with the soil classification. These are shown in the soil legend. Since treatment applied to the watersheds may have a direct influence on the amount and velocity of surface and subsurface runoff, the present erosion conditions become of paramount importance.

The hydrology of the entire profile seems to be conditioned by the surface soil and the moisture content at the time precipitation occurs. Infiltrometer studies show that depth of litter did not influence the infiltration rates to any significant degree as long as there was some litter cover on the ground. Texture, structure, and depth of the "A" horizon were the physical conditions which seemed to have the greatest influence on surface runoff. Infiltration rates varied according to the type of use, the amount of compaction, the moisture content, the clay content, and the stability of soil aggregates.

Colman soil-moisture elements have been installed at eight stations in the area. At each station elements were placed at 6-, 12-, 24-, 36-, and 48-inch depths. These will be effective in following moisture and temperature changes during treatment.

No marked relationship has appeared between soil type and vegetation. The prevailing influence of the soil on the vegetation is chiefly through its depth and water-holding capacity. Deep soils with a high water-holding capacity permit higher moisture-requiring trees to grow, whereas shallow soils cannot hold enough water to tide these trees over the dry periods.



The total density of the timber stand varies tremendously

The driest part of the watershed, an exposed south-facing slope, has a total tree basal area for all trees 0.6 inch d.b.h. and over of slightly less than 40 square feet per acre. In contrast, the most favorable part of the watershed for tree growth, a nearly level north-facing slope, has a total tree basal area of about 335 square feet per acre, over eight times as much.

The variation in the amount of timber per acre is due primarily to changes in moisture conditions resulting from differences in aspect and soil depth.

A wide variety of growing conditions exists in the three forks. Drier situations are much more common on the North Fork and moist situations are more common on the South Fork. Middle Fork, with a westerly aspect, is intermediate between the two. Averaging the conditions of each fork results in less variation between forks than between the dry and moist sites on each fork. However, certain variations still are apparent:

Trees 12 inches d.b.h. and larger make up 60 percent of the total basal area on South Fork, 52 percent on Middle Fork, and 47 percent on North Fork. Less favorable growing conditions on North Fork, and to a lesser extent on Middle Fork, result in slower growth and smaller trees as compared to the South Fork (fig. 1).

Gambel oak occurs mostly on the dry sites, not being able to compete with white fir and Douglas-fir on moist sites.



Figure 1.--Timber composition (12 inches d.b.h. and over)

## North Fork

PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP: WWWWWW: DD : 0000000000: : 47%

	52.2	20.1	4.1	22.2	1.4
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP					
WWWWWWW					
DD					
0000000000					
:					
:					
47%					

Middle Fork

[illegible]

## South Fork

PPPPPPPP PPPPPPPPPPPPPPPP PFFFFFPFFPFPFPPPP:	WWW WWW WTW TWW TW WW	:	DDD:	OOO O O :		: 60%
59.4	25.5		5.8	8.0	1.3	

(Basal area (as percent of total basal area))

P - Ponderosa pine, W - White fir, D - Douglas-fir, O - Oak, Others

Commercial sawtimber volume in board feet per acre (gross)

is much higher on the South Fork than on the North or Middle Forks  
because:

(a) Fewer of the trees 12 inches d.b.h. and over on South Fork are noncommercial species (13 percent as against 36 percent on North Fork and 37 percent on Middle Fork (table 1)).

Table 1.--Comparison of timber stand - North, South, and Middle Forks - Workman Creek (per acre averages)

	Number of trees			Basal area			Sawtimber
Area	All species	Conifers	All species	Conifers	Conifers	Conifers	
	1" and over	12" and over	12" and over	1" and over	12" and over	12" and over	12" and over
	(Number)	(Number)	(Number)	(Sq.ft.)	(Sq.ft.)	(Sq.ft.)	(Ft.b.m.)
North	1,140	39	25	174.43	81.92	62.61	13,046
South	991	52	45	200.84	119.84	108.75	20,520
Middle	1,110	49	31	193.21	100.36	77.02	14,837

(b) South Fork has more trees per acre 12 inches d.b.h. and over.

(c) The trees are taller and slightly larger in basal area.

Maximum volumes on Workman Creek run as high as 50,000 board feet per acre.



Timber composition is changing (fig. 2).

Figure 2.--Timber stand composition by diameter classes

1"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWWWWWWWWWWWWWW	DDDDDD	0	X
	40.8	42.6	14.0	.6	2.0
2"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWWWWWWWWWWWW	DDDDDD	00	X
	50.0	31.9	12.7	3.2	2.2
3"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWWWWWW	DDDDDD	00	XX
	53.4	22.7	11.2	4.4	3.3
4"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWWWW	DDDDDD	0000	XXX
	55.6	18.7	11.3	9.1	5.3
5"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWWWW	DDDDD	000000	XXXX
	54.3	15.1	10.9	11.8	7.9
6"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWW	DDDDD	0000000	XXXXX
	51.5	14.9	9.8	13.7	10.1
7"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWW	DDDDD	00000000	XXXXXX
	48.5	14.8	9.4	15.0	12.3
8"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWW	DDDDD	00000000	XXXXX
	49.0	14.9	10.0	15.4	10.7
9"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWW	DDDDD	0000000000	XXXX
	50.0	12.2	9.3	19.9	8.6
10"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWWWW	DDD	00000000000000	XX
	43.7	17.2	5.5	28.4	5.2
11"	PPPPPPPPPPPPPPPPPPPP	WWWWWWWWWW	DDD	000000000000	XXX
	45.8	17.5	6.5	23.7	6.5
12" and up	PPPPPPPPPPPPPPPPPPPP	WWWWWWWWWW	DDD	00000000000000	XX
	46.8	18.1	6.0	26.4	2.7

P - Ponderosa pine, W - White fir, D - Douglas-fir, O - Oak,  
X - Other species

1. Gambel oak is apparently being crowded out by coniferous timber species; from 28.4 percent of the 10-inch d.b.h. class, it makes up a decreasing percent of each smaller diameter class till it comprises only 0.6 percent of the 1-inch d.b.h. class.

2. Douglas-fir appears to be increasing--from 6 percent of the 12-inch d.b.h.-and-over class to 14 percent of the 1-inch class.

3. White fir also shows an increasing trend, particularly in the small diameter classes--from 18.7 percent of the 3-inch class to 42.6 percent of the 1-inch class.



4. Ponderosa pine, which shows an increasing trend from the 12-inch class down to the 3-inch class, shows a rapid dropping off in the 2-inch and 1-inch classes--from 58.4 percent of the 3-inch class to 40.8 percent of the 1-inch class (fig. 2).

#### Transpiration

Transpiration by trees is an important factor in water use on fully stocked forest land, particularly from those trees that have all the water they require. Transpiration varies directly as leaf area varies when soil moisture is above the wilting point--the more leaf area, the greater the transpiration. Leaf area for any given species varies with leaf weight, and within certain limits foliage weights vary with tree diameters. This relation between tree diameter and foliage weight can be expressed in a regression formula from which foliage weights can be computed from tree diameter data. To illustrate, the figures shown in table 2 for foliage weights in kilograms per acre are for the three forks of Workman Creek (figures for white fir and oak are problematical since accurate constants for use in the regression formula are not available at present but measurements are in progress).

Table 2.--Foliage weight - Kg per acre

Area	: Ponderosa : : pine	: White fir : : White fir	: Douglas- : : fir	: Oak : : Oak	: Total
North	1,556.37	601.83	250.26	1,355.70	3,764.16
South	1,716.39	911.47	240.84	721.00	3,589.70
Middle	1,413.94	761.08	425.80	1,600.10	4,200.92

Ponderosa pine -  $\log W = 1.67 \log D - 0.73$   
Douglas-fir -  $\log W = 1.96 \log D - 0.91$   
Canyon live oak -  $\log W = 2.66 \log D - 1.36$



### Understory vegetation

Understory vegetation is sparse throughout the watershed. Grass density averages only 0.04 percent and leaf area of forbs and shrubs averages 1 percent. One hundred foot transects have been established over the watersheds to follow any changes in grass or forbs cover.



## APPENDIX B

### SOIL DESCRIPTIONS

#### General

There are three general groups of soils which include the diabase soils, the sandstone soils, and the quartzite soils. Slate was found to be of minor influence in the development of soil No. 7. The diabase soils produce by far the best forest, most of which is Douglas-fir. The sandstone and quartzite soils in general have western yellow pine forest.

These soils are sedentary soils and erosion has been practically nonexistent. When tested with hydrochloric acid, effervescence did not take place on the soil from any horizon.

The A and B horizons in general have either granular or crumb structure. The C horizons, which is clay for most of the area, when dry has a blocky structure and when wet it has massive structure.

#### Soil No. 1

2211 - Sod - Z = Soil No. 1  
B - 0 - SS, Di

The A horizon is moderately heavy and varies from 4 to 6 inches in depth. It has a crumb structure and the color is dark brown to black. It has an 8 percent slope and is covered well with sod. There is no apparent erosion. The parent material is sandstone, although there are a few large sandstone rocks appearing through the surface of the soil. Diabase evidently played an important part in the development of this soil. Diabase rock can be found near the boundary of the soil body and the C horizon has the yellow color and heavy texture that is characteristic of the diabase soils.



The B horizon is moderately heavy to heavy in texture and is 18 to 22 inches in depth. This horizon has a crumb structure and is black in color.

The C horizon is heavy textured. It has massive structure in the soil bodies found in the Peterson pasture. It is yellow in color and a blue clay was found below the yellow in the small body at the west end of the Peterson pasture. The C horizon of the soil body in the Watkins mining claim is dark brown to black in color and has definite structure, the structure being blocky.

Three small areas of this soil were mapped and their location has been given above. The most outstanding characteristic of this soil is its poor drainage. Free water was found in the A, B, and C horizons and in places there was water in small puddles on the surface. One test hole was 38 inches deep and in 24 hours water was within 12 inches of the surface.

The small area south and a little east of the Watkins mining claim and included within his fence is partly a diabase soil and partly a sandstone soil. It is located on a contact between diabase and sandstone.

Hydrochloric acid produced no effervescence on any of the horizons of this soil.

Soil No. 2

3313 - None - None = Soil No. 2  
B - 0 - SS, Di

The A horizon is medium in texture and is 7 to 9 inches deep. It has a granular structure and is light grey in color. It has a 7 to 10 percent slope. There has been some gullying in the past but at present grasses and oaks are in abundance and erosion is not active. The parent



material is predominantly sandstone, although some diabase is present.

There are sandstone nodules throughout the A horizon.

The B horizon is moderately heavy to heavy in texture. It begins about 8 inches from the surface and no change in profile could be observed to a depth of 6 feet. A 4-foot soil tube was driven in the bottom of each 6-foot hole and when removed no change in the soil could be seen. It is probable that at a depth of about 28 or 30 inches the C horizon begins but inspection of the profile does not show a distinct break between the horizons as was found in all other soil bodies in the area. This horizon has a crumb structure and is black in color.

The area known as the upper pasture in the Peterson pasture has evidently been under cultivation in years past. Grass is not abundant.

Hydrochloric acid gave no effervescence on any of the horizons.

This soil has probably developed under mountain meadow conditions. However, a small area has been mapped that developed under forest cover. In this case the A horizon is dark brown and the B horizon is light brown in color. A very small amount of organic material covers the surface under forest cover.

### Soil No. 3

321(14) - 1-1/4R - 20Z(XY) = Soil No. 3  
C - 0 - Di, SS

Soil No. 3 is predominantly a diabase soil, although sandstone has worked over and into the profile so that it is very difficult to find pure areas of diabase. The general location of this soil body is northeast and east of the Peterson ranch and a small finger cuts between the two areas of soil No. 2.

The A horizon is of medium texture and varies greatly in depth, averaging about 2 to 9 inches. It has a granular structure with a good



covering of organic material. The color varies from dark brown to black. The average slope for this soil is 20 percent.

The B horizon is also of medium texture with a granular structure, and is slightly lighter in color than the A horizon. The depth varies greatly between 3 and 12 inches.

The C horizon is moderately heavy to heavy in texture with a blocky structure. The color of this horizon is yellow to yellowish red. The C horizon is apparently very deep as this fact was easily observed on road cuts and places where the bank had caved off along the creek.

The percent of rock covering the surface of this soil is about 20 percent. The most of the rock is larger than 6-inch diameter, though a considerable amount of smaller rock is present.

No effervescence took place on the soil from any horizon when hydrochloric acid was applied.

Soil No. 4

2214 - 1/4 0 - 30XYZ = Soil No. 4  
C - 0 - SS, Qt.

The profile described below is 50 feet east of U.S.B.M. There are three bodies of soil number 4. The largest of these lies north and north-east of the Peterson ranch; another lies west and southwest of the Peterson ranch; and the other is southeast of the Peterson ranch.

The A horizon is moderately heavy and is 4 to 6 inches in depth. It has a granular structure and the color varies from **grey** brown at site described to black under heavy forest and to a reddish brown in small clearings and scattered forest cover.

The B horizon is moderately light to medium in texture with no definite zonal difference between the A and B horizons, and is 10 to 12



inches in depth. It has a granular structure and is light brown to red in color.

The C horizon is moderately heavy to heavy and occurs approximately 16 inches below the surface. It has a blocky structure and is yellowish red to red in color.

The average slope of this soil is 16 to 17 percent. The parent material is largely sandstone with quartzite being found in places.

Hydrochloric acid gave no effervescence when applied to each horizon. The organic material varies from a trace up to 2 inches under heavy forest. The percent of rock covering the surface is about 30 percent and their size ranges from small pebbles to very large rock. The amount of rock in each size breakdown, as given in the Guide for Mapping at the end of this report, is about equal.

#### Soil No. 5

5155 - 1/4 0 - 35XYZ = Soil No. 5  
C&F - 0 - SS, Qt

Soil No. 5 is located generally along the ridge northeast of Peterson ranch and includes the sandstone cliffs northeast of Peterson ranch. It is broken into the north section, the middle section, and the south section for convenience of discussion. The profile development of this soil has been slow. A good deal of erosion has taken place in the middle section. This was the only place in the entire area surveyed where erosion has been recently active. The area of erosion was small compared to the size of the soil body and therefore the erosion was classified as slight. The slope of the middle section is about 16 percent while the north and south sections have 40 and 42 percent respectively.

All three horizons are textured and have an undifferentiated structure. The A horizon is brown in color and 2 to 3 inches in depth.



The B horizon is reddish brown in color and approximately 8 inches in depth. The C horizon is red in color and begins 10 to 12 inches from the surface. Water is absorbed rapidly through this profile.

The surface is covered by 35 percent rock ranging in size from pebbles to very large rock. The south section has a white sandstone covering it while the middle and north sections have a red sandstone. The sandstone cliffs mentioned above are the red sandstone.

The trees in this soil are small and very scattered generally. The organic material covering the surface is 1/2 inch thick on the south section while the middle and north sections have a trace to 1/4 inch. There is very little evidence of decay of the organic material.

The parent material is sandstone with a small amount of quartzite scattered over the surface.

No effervescence occurred when hydrochloric acid was applied to each horizon.

Soil No. 6

3112 - 1R - 40 XYZ  
D&E - 0 - Di, Gr, SS, Qt = Soil No. 6

The general location of this soil is the beginning of the North Fork drainage of Workman Creek and extending along the ridge north of Peterson ranch. It narrows down to the North Fork itself and extends almost to the North Fork Dam.

The A horizon is medium in texture and from 1 to 3 inches in depth. It has a granular structure and is grey brown in color. This horizon feels light and fluffy when handled and does not seem to compact. About 40 percent of the surface is covered with rock.

The B horizon is medium texture but is lighter in color than the A horizon. It is from 3 to 6 inches in depth and has a definite



granular structure.

The C horizon is quite different from anything else found in the area. There are areas in which the C horizon has a crumb or granular structure and is medium in texture. Other areas are heavy textured and either blocky or undifferentiated in structure. This lack of uniformity is due to the parent materials. Diabase and granite occur in about equal proportions, with smaller amounts of sandstone and quartzite. The small granite and diabase crystals have weathered to form the clay C horizon, while the large crystals have remained almost unweathered which causes a coarse crumb structure.

The yellowish red color remains quite constant over the soil body for the C horizon.

The organic material covers this soil about 1 inch over the entire area.

The lower portion of the soil body has a slope of about 25 percent while the upper part has a slope of 35 to 40 percent. Erosion is not noticeable. There is no effervescence with hydrochloric acid.

Soil No. 7

$\frac{5116 - 1/4 O - 20 XYZ}{C - O - Qt, SS, Sl} = \text{Soil No. 7}$

This soil is located along the ridge northwest of the Peterson ranch. It is primarily a quartzite soil. Sandstone is present and outcroppings of slate are also found. The slope of this soil ranges from a little less than 10 percent to 20 percent.

The A horizon is light textured and is 2 to 3 inches in depth. Little structure has developed, but what has is granular. It is reddish brown in color.



The B horizon is light sandy texture, reddish brown in color, with an undifferentiated structure.

The C horizon is light in texture and reddish brown in color. It begins about 15 inches from the surface. Its structure is also undifferentiated.

Rock paving covers the surface of this soil and keeps erosion in check. The average cover of organic material is 1/4 inch and there is very little evidence of its decay.

There was no effervescence from hydrochloric acid in any of the horizons. Hydrochloric acid was also dropped on several different pieces of the slate found on top of the ridge but no effervescence occurred.

About 20 percent of the surface is covered with rock and rock occurs throughout the profile.

#### Soil No. 8

2215 - 1/8R - 1 XY = Soil No. 8  
B&C - 0 - SS, Qt.

Soil No. 8 has been formed by water washing sand and fines into low places. Only slight profile development has taken place. In general, there is very little organic material covering this soil. The slope ranges from 8 to 12 percent.

The A horizon is moderately heavy in texture and is 4 to 6 inches in depth. A granular structure has developed which is brown in color.

The B horizon is moderately heavy textured and from 4 to 7 inches in depth. It has granular structure and is reddish brown in color.

The C horizon is medium to moderately heavy in texture, blocky structure, and reddish brown in color.

The parent material of this soil is predominantly sandstone. Quartzite has played some part in the development of this soil also.



Hydrochloric acid on soil from each horizon produced no effervescence. Only three small areas of this soil were mapped.

Soil No. 9

4234 - 1/8 0 - 25 XYZ = Soil No. 9  
A&F - 0 - SS, Qt

Soil No. 9 is located on top of Aztec Peak. It is a sedentary soil and some of the fines have been washed to lower areas. Sandstone layers are on the surface of this soil just south of Aztec flag. The area of exposed rock here is small, however, compared to the size of the soil body. About 25 percent of the surface is covered with rock.

The A horizon is moderately light textured and 4 to 5 inches in depth. It has a crumb structure and is dark brown in color.

The B horizon has a medium texture and is 6 to 9 inches deep. It has a granular structure and is reddish brown color.

The C horizon is moderately light to medium textured and is lighter and more red in color than the B horizon. It is almost without structure and what little has developed is granular in nature.

The entire profile has a great number of rock which are 1 inch or less in diameter.

When hydrochloric acid was applied to soil from each horizon, no effervescence occurred. The west side of this soil body has a slope of about 45 percent, while on top the slope is 6 to 10 percent.

Where there is no duff or organic material covering the surface, this soil has an excellent rock paving, thus holding erosion in check. Little organic material is present on this soil.

Sandstone and quartzite of about equal amounts make up the parent materials.



Soil No. 10

3214 - 1/2R - 15 XYZ = Soil No. 10  
B - 0 - SS

This soil is located south of the upper pasture of the Peterson ranch. It is a red sandstone soil with a slope of about 10 percent. The forest cover on this soil is western yellow pine. There is about 1/2 inch of organic material covering the surface and about 15 percent of the surface is covered with the sandstone rock.

The A horizon is medium textured and 4 to 6 inches in depth. It has a granular structure and is dark brown in color.

The B horizon is also medium in texture and is 4 to 8 inches in depth. It is light grey in color and is granular in structure.

The C horizon is heavy textured, is red, mottled, and has grey streaks through it. It has a blocky structure.

Hydrochloric acid produced no effervescence on the soil from any horizon from this profile.

Soil No. 11

3214 - 1/2 O - 40 - XYZ = Soil No. 11  
C - 0 - SS, Qt

The soil is located northeast of Peterson ranch. It has a 15 to 20 percent slope. It is derived primarily from sandstone, with some quartzite present.

The A horizon is medium in texture and 4 to 6 inches in depth; has a granular structure and is dark brown in color.

The B horizon is medium in texture and 12 to 14 inches deep. It has a crumb structure and is light brown in color.

The C horizon is moderately heavy to heavy in texture, is red in color and in general almost 2 feet to the red clay. The red clay is not



as extensive in this soil as in some of the other soils. It has a blocky structure.

Hydrochloric acid gave no effervescence when applied to soil from each horizon.

The organic material covering the surface is about 1/2 inch thick. It shows very little or no evidence of decay.

#### Soil No. 12

6456 - Shrubs - 75 XYZ = Soil No. 12  
F - 0 - Qt. SS

Soil No. 12 is located above soil 11 on the slope. It is an extremely rocky soil and is extremely steep. The surface is covered with rock of all sizes to the extent of about 75 percent. Much of this rock is exposed bedrock. The slope of this soil is about 60 percent.

The profile development of this soil has been slow or it has been removed as fast as it has developed because of the steepness of the slope. The north end of this soil body is the only place any profile development has occurred and this was questionable. Color is light grey to brown, with a sandy loam texture. One set of samples was taken in the north area and only the A and B horizons were obtained in this instance.

Hydrochloric acid on this soil produced no effervescence. The most important parent material of this soil is quartzite. Sandstone is also found frequently over the area.

Shrubbery covers most of this soil. Small pines are present but there is such a small amount of soil that they have not developed.

#### Soil No. 13

3214 - 1/2 0 - 45 XYZ = Soil No. 13  
D - 0 - SS, Qt

Soil No. 13 is located south of the main dam on Workman Creek. The runoff from this soil all goes below the South Fork Dam.



The A horizon is medium in texture and is 4 to 6 inches in depth. It has a granular structure and is dark brown in color.

The B horizon is medium in texture and 8 to 10 inches in depth. It has a crumb structure and is light brown in color.

The C horizon is heavy textured. It has a blocky structure when dry but when wet it had a massive structure. It is red in color.

When hydrochloric acid was applied to soil from each horizon, no effervescence took place. This soil has a slope of 25 percent.

The parent material is sandstone, most of which is white. A little quartzite was found over the soil body and no doubt had some influence on the development of this soil.

#### Soil No. 14

3114 - 1-1/4 G - 5 XYZ = Soil No. 14  
C&D - 0 - Di

Soil No. 14 is undoubtedly the purest diabase soil in the area. It has a slope between 12 and 25 percent. Douglas-fir makes up most of the forest that covers this soil. The organic material covering the surface is about 1-1/4 inches in depth and is quite well decayed.

The A horizon is medium in texture and 3 to 4 inches deep. It has a granular structure and is dark brown in color.

The B horizon is medium textured. Its depth is 4 to 8 inches and it also has a granular structure. This horizon is slightly lighter in color than the A.

The C horizon is heavy textured and has a blocky structure where dry and massive structure where wet. Two colors are found in this horizon - red and yellow.

No effervescence was seen when hydrochloric acid was applied to soil from each horizon.



Soil No. 15

3114 - 1-1/2G - 2 XYZ = Soil No. 15  
A&B - 0 - Di

This soil is very similar to soil No. 14 except for slope. The slope of 15 is from 5 to 10 percent. It is the most level soil in the area surveyed. Pine trees are more in abundance than fir trees in this soil even though it is a diabase soil. The organic material covering the surface varies from 1/2 inch to over 2 inches. Its small degree of slope probably has something to do with the relatively thick layer of organic material.

The A horizon is medium in texture and 3 to 4 inches in depth. Its structure is granular and its color is dark brown.

The B horizon is medium textured and is 4 to 8 inches in depth. It has a granular structure and is lighter in color than the A horizon.

The C horizon's texture is moderately heavy and has a blocky structure. The color of this horizon is reddish brown.

Hydrochloric acid applied to soil from each horizon produced no effervescence.



Table 1. Soil key for mapping Workman Creek watershed

Symbol used

to record 1221 - 3R - 15Y = Soil - Organic material - Rock  
data: B - 0 - SS Slope - Erosion - Parent material

Numer-

al	Texture	Depth	Structure	Color
1	Heavy	0-3"	Granular	Black
2	Moderately heavy	4-6"	Blocky	Gray brown
3	Medium	7-9"	Crumb	Light gray
4	Moderately light	10-12"	Columnar	Dark brown
5	Light	13-15"	Undifferentiated	Brown
6	Undifferentiated	16" or over		Reddish brown

Organic material - Depth in inches - Degree of decay

O - Very little evidence

R - Moderate decay

G - Well decayed

Rock - Percent of rock covering surface - Numeral

X - Pebbles  $\frac{1}{8}$  - 2" in diam.

Y - Cobbles 2-6"

Z - Larger 6" and up

Slope		:	Erosion	:	Parent material
Let-	Slope	:	Nu-	:	Let-
ter		:	meral	:	ter
A	0-5%	:	0	Slight	SS Sandstone
B	6-10%	:	1	Gully forming	Qt. Quartzite
C	11-20%	:	2	Sheet-active	Di Diabase
D	21-30%	:	3	Active sheet &	Gr Granite
E	31-40%	:		gully	
F	41% &	:		Evidence of sur-	
	over	:	4	face sealing	
		:			

For example, in the top line of the symbol used to record data, the first figure refers to texture--in this case, heavy. The second figure refers to depth--in this case, 4 to 6 inches. The third figure refers to structure--in this case, blocky. The fourth figure refers to color of surface soil--in this case, black. The second set of figures--in this case 3R--refers to a 3-inch depth of organic matter and a moderate degree of decay. The last set of figures--15Y--indicates 15 percent of the surface covered with cobbles 2 to 6 inches in diameter. The first letter in the lower line refers to slope--in this case, 6 to 10 percent. The second figure--0 in this case--refers to slight erosion. The third set of figures--SS in this case--refers to sandstone as the parent material.